Garibaldi (6)
(see under tungsten)

Keystone (3)
(see under copper)

New Find (7)
(see under copper)

Richmond (2)
(see under lead)

BARIUM

Properties—Barium is a soft silver-white metal that is like lead in appearance. It belongs to the alkaline earth group and resembles calcium chemically. Although the metal is not especially heavy, many of its compounds have high density, and many of their uses depend upon this property. The pure metal is unstable and is the most active of the alkaline earth metals except radium. It reacts vigorously with water to produce hydrogen and barium hydroxide. All soluble barium salts are very poisonous. They give a green color to the flame when placed in a fire. Other properties are given in the table on page 12.

Uses—The metal has few uses, but its compounds have several important uses, which are mentioned under barite in Part I of this report. A thin film of barium is used to lubricate the rotor operating at high speed in a vacuum in an X-ray tube, where ordinary lubricants fail. A high-nickel alloy is used in spark plugs, and alloys with lead have been made, but at the present time the only important use for barium metal is as an alloy with magnesium and aluminum as a "getter" in electronic tubes. (A "getter" is a volatile metal introduced into a vacuum tube for removing traces of undesirable gases.) A commonly used "getter" alloy contains one part barium, one part aluminum, and two of magnesium.

Production—In 1950 there were only two reported producers of barium in this country; their total output amounted to several thousand pounds annually. Barite is produced in large quantities in the United States, and small amounts have been mined in Washington in the past, but all but an insignificant portion of this production is for industrial mineral uses rather than as an ore of barium.

Prices—The price of the metal in 1932 was $7.50 to $10.00 per pound, and in 1943 it sold for from $5.00 to $8.00 per pound. In 1950 one producer quoted a price of $6.00 per pound in 1,000-pound lots. Early in 1954 the price of barium metal in rod form was $13.50 per pound in 5- to 10-pound lots.

Ore minerals—The principal ore mineral is the sulfate, barite, $BaSO_4$, containing 58.8 percent barium; but the carbonate, witherite, $BaCO_3$, containing 69.7 percent barium, is not uncommon. Barium is widely distributed as a minor constituent of silicate minerals throughout the igneous rocks.

Geology—Barite occurs as pods, large veins, and beds in sedimentary rocks and as cementing material in sandstone. It is a common gangue mineral in ore deposits.

Occurrences

The occurrences of barite, the principal ore mineral of barium, are listed in Part I of this report.

BERYLLIUM

Properties—Beryllium, also called glucinum, is a steel-gray to silver-white nonductile metal which is brittle at room temperatures. It is similar to magnesium and aluminum in appearance and chemical composition. It weighs only about two-thirds as much as aluminum but is much harder (it will scratch glass but not quartz), has a much higher melting point, is more corrosion resistant, and is four times as elastic as aluminum and almost as elastic as steel. It is capable of taking a high polish. An interesting property is that of transmitting sound at a very high velocity, about 2.5 times that of steel, which apparently has the next highest sound-transmission velocity. The metal has a high melting point, but it distills rapidly at a temperature only slightly greater than its melting point. Other properties are given in the table on page 12.

Uses—Military uses during World War II accounted for approximately 99 percent of domestic consumption, but peacetime uses are increasing. The pure metal is used in neutron generators and for windows in X-ray tubes. The metal and its compounds are of major interest in the atomic-energy program for its moderating effect upon the fast neutrons emitted by the fission of U-235 and plutonium, and probably for other undisclosed applications. Beryllium oxide is used in ceramics such as spark plugs and is receiving much attention in the field of cermets, combined metals and ceramics, for such superduty refractory applications as jet engines and gas turbines. Beryllium compounds are used in fluorescent screens and lights, but since mid-1949 this use has declined sharply due to the use of substitutes. The high velocity of sound in pure beryllium metal may bring applications in the field of acoustics. The major use for the metal is in alloys with iron, aluminum, magnesium, zinc, nickel, and copper, but especially with copper, where it develops properties somewhat analogous to those imparted to steel by carbon. Addition of up to a few percent of beryllium to copper produces a series of alloys that are heat treatable, high strength, highly conductive, corrosion resistant, fatigue resistant, and nonsparking. These alloys have many exacting uses in the manufacture of electrical and other instruments and equipment.

Production—A large part of this country's beryllium supply is imported, and the demand may be expected to increase in the future, so the pressure for discovery of new domestic supplies probably will increase. The only production to date in Washington was a few hundred pounds of beryl mined from the Cannon (Calispell Peak, Railway Dike) pegmatite deposit in central-eastern Stevens County in 1952.

Prices—The price for beryllium usually is quoted as price per short ton unit (20 pounds) of BeO in beryl ore containing 10 to 12 percent BeO. For many years beryl ore was quoted at $3.00 per short ton unit, but after 1940 the price rose to $7.50 in 1942 and $14.50 in 1944. The following year the price dropped to $9.00, but by 1948 it had risen to $24.00. In September 1952 it was $38.50, and in March 1953 it was at a record high of as much as $50.00 for the best grades.

Ore minerals—The only commercial ore mineral of beryllium is beryl, a complex beryllium aluminum silicate, $Be_3Al_2(SiO_3)_6$. When pure it contains 13.9 percent BeO, but it is seldom pure, and the usual range is from 9 to 11 percent BeO. Other beryllium minerals, which if found in sufficient quantity could be sources of the metal, are phenacite, Be_2SiO_4, containing 45.5 percent BeO; chrysoberyl, $BeAl_2O_4$, containing 19.7 percent BeO; helvite, $3(Mn,Fe)BeSiO_4 \cdot MnS$, containing 12.6 to 13.5 percent BeO; gadolinite, $Be_2FeY_2Si_2O_{10}$, containing 10.7 percent BeO; and beryllonite, $NaBePO_4$, containing 19.7 percent BeO. Of these minerals, only beryl is known to occur in Washington.

Geology—Beryl occurs almost exclusively in pegmatite deposits in granite, in which it seldom constitutes more than 1 percent of the total. It occurs as distinct hexagonal crystals or as irregular masses, some of which may weigh as much as several tons. It is distributed sparsely and erratically, but in some pegmatites it is concentrated in recognizable zones. Most of the other potential beryllium ore minerals also occur in pegmatites, but helvite has been found in contact-metamorphic deposits.

Occurrences

The beryl occurrences in Washington are described in Part I of this report. The Cannon (Calispell Peak, Railway Dike) deposit is described in a little more detail on page 356 here in Part II under uranium, Stevens County. Another reported occurrence of beryl, not included in Part I, is described in Part II, page 37, under the name of Gemini, under chromium, Ferry County.

BISMUTH

Properties—Bismuth is a crystalline metal having a hardness of 2.0 to 2.5, a high luster, and white color with a reddish tinge. It is brittle, but when heated to 100° C. is slightly ductile. Recent research has resulted in the manufacture of ductile bismuth which can be made into wire and ribbon and which will not age-harden or crystallize. Like antimony and gallium, bismuth expands (3.3 percent) when it solidifies from a melt. It is the most diamagnetic (repels a magnetic field) of the metals. It oxidizes easily, producing an iridescent film, and when heated in air it burns with a blue flame. Its electrical conductivity is low, and only mercury has a lower thermal conductivity. Chemically, it is similar to arsenic and antimony. Other properties are shown in the table on page 12.

Uses—The recently developed ductile bismuth wire and ribbon are being used in electrical instruments, and bismuth has been used as an additive in stainless steel. The largest use as a metal is in alloys with lead and, to a lesser extent, with tin and cadmium. These alloys have some valuable properties in common with pure bismuth, particularly that of expanding when solidifying and of having low melting points—as low as 100° F. (38° C.). The low-melting point alloys are used for special solders, safety fuses, automatic sprinklers, dental amalgams, and for making sharp castings of objects which would be subject to damage by high temperatures. Because of its low absorption cross section for thermal neutrons, bismuth has attracted attention as a possible coolant for nuclear reactors. The greatest use (about 80 percent) is in the nonmetallic state, as compounds in medicine and industrial chemistry.

Production—The United States is about 50 percent self-sufficient in bismuth. The metal is reported to have been produced at four plants in this country in 1950. All this production was a byproduct of smelting lead and copper ores. No production has been reported from Washington.

Prices—For many years the bismuth market was effectively controlled by agreements among the relatively few foreign producers, and the United States market closely followed that of London. The New York price ranged between $1.70 and $2.15 per pound in 1910, rose as high as $4.00 in 1916, had returned to the earlier level by 1921, and has remained at about that level ever since, with a low of $1.00 in 1930 and a high of $3.35 in 1926. Since 1930 the price has been steady, rising intermittently by small increments from $1.00 per pound in 1930 to $2.25 in September 1950, at which price it has remained to June 1955. Bismuth ores have rarely been marketable as such in the United States, but at times lead or copper ores containing 3 percent or more of bismuth have received payment for their bismuth content. In general, bismuth ores should contain at least 10 percent of bismuth metal, and ores as rich as 65 percent are available from foreign countries. It is customary for the lead and copper smelters to consider the bismuth content of ore received as being objectionable rather than adding to the value of the ore.

Ore minerals—Bismuth commonly occurs native. The native metal and the sulfide, bismuthinite, Bi_2S_3, containing 81.2 percent bismuth, are its principal ores. The only bismuth minerals reported in Washington are the lead-bismuth sulfide, cosalite, $2PbS \cdot Bi_2S_3$, containing 43.5 percent bismuth, and the basic carbonate, bismutite, $Bi_2O_3 \cdot CO_2 \cdot H_2O$, containing 79.0 percent bismuth. Other relatively rare bismuth minerals are two silicates, the oxides, carbonate, molybdate, vanadate, arsenate, and several sulfosalts and tellurides.

Geology—In quartz veins bismuth occasionally is the principal ore, but generally it occurs as an accessory in many minerals and ores of copper, gold, silver, lead, and zinc. In places it is associated with tin, elsewhere with cobalt and uranium, and with tungsten. In addition to vein deposits, it is found in contact-metamorphic deposits and in pegmatites. In Washington, bismuth minerals have been found in a pegmatite, in several wolframite-bearing quartz veins, and in mixed copper-gold-silver-lead-zinc ores.

Occurrences

The map showing the numbered bismuth occurrences is plate 3, on page 11 in volume 2.

CHELAN COUNTY

Keefer Brothers (1)
(see under molybdenum)

FERRY COUNTY

Talisman (1)
(see under copper)

GRANT COUNTY

Black-Rosauer (1)
(see under silver)

KING COUNTY

Pedro
(see under copper)

OKANOGAN COUNTY

Boundary
(see Wolframite under tungsten)

Ferris R. Ford
(see Wolframite under tungsten)

Hatfield
(see Wolframite under tungsten)

Key (3)
(see under silver)

Mountain Beaver (2)
(see under gold)

Wolframite (1)
(see under tungsten)

SNOHOMISH COUNTY

Lucky Strike (1)
(see under copper)

Silver Coin (2)
(see under gold)

STEVENS COUNTY

Calispell Peak
(see Cannon under uranium)

Cannon (2)
(see under uranium)

Germania (5)
(see under tungsten)

Maple Leaf
(see Melrose under silver)

Melrose (1)
(see under silver)

Paragon
(see Melrose under silver)

Railway Dike
(see Cannon under uranium)

S. L. (4)
(see under tungsten)

Tungsten King (3)
(see under tungsten)

BORON

Properties—Boron is generally considered a nonmetallic element, but sometimes it is classified as a metal, and in some respects it does act as a metal. Chemically, boron is similar to silicon and carbon and is markedly nonmetallic in its reactions. It acts as a reducing agent, and with few exceptions it is trivalent. In some physical properties it slightly resembles the metals. It forms black crystals nearly as hard as diamonds but also occurs in an amorphous form. The melting point is very high and the heat resistance is high, as is also the resistance to an electric current, although electrical resistance decreases with increased temperature. Other properties are given in the table on page 12.

Uses—Boron is added to melts of copper and other metals to deoxidize the metal before casting. Boron master alloys are added to medium- and high-carbon steels to confer depth hardenability and to intensify the effects of other ferro-alloys used, allowing large reduction in the amounts of other ferro-alloys needed to produce the desired effects. Boron carbide is the hardest commercial synthetic substance known; it is used for abrasives, for certain heavy-duty wear-resistance applications, and, because of its excellent refractory qualities, in jet engines. Metallic boron has only limited uses, but the nonmetallic compounds, borax and boric acid, have a very wide range of important uses as oxidation resistant coatings on metals, in glass manufacture, as fluxes, in soap, as trace-element plant food, and in industrial chemical processes; also, they have a large number of minor uses.

Production—Practically all of the minerals from which boron is extracted are produced in the desert areas of southern California. None has been produced in Washington, and no production may be anticipated in the future.

Prices—Elemental boron was quoted in 1955 at $10 to $13 per pound for metal of 90 to 92 percent purity and $12 to $15 per pound for metal of 95 to 97 percent purity.

Technical grade borax sold at $41.50 per ton during World War II, rose to $44.50 in 1946, and was selling at $33.25 per ton in the latter part of 1950.

Ore minerals—Boron minerals which have been produced commercially are borax, $Na_2B_4O_7 \cdot 10H_2O$, containing 36.6 percent B_2O_3; kernite, $Na_2B_4O_7 \cdot 4H_2O$, containing 51.0 percent B_2O_3; colemanite, $Ca_2B_6O_{11} \cdot 5H_2O$, containing 50.9 percent B_2O_3; ulexite, $NaCaB_5O_9 \cdot 8H_2O$, containing 43.0 percent B_2O_3; sassolite, H_3BO_3, containing 56.4 percent B_2O_3; and boracite, $Mg_6Cl_2B_{14}O_{26}$, containing 62.4 percent B_2O_3. At least four boron-bearing silicate minerals are known in Washington, but none of these is now considered as an even remotely possible ore of boron. These are dumortierite, $8Al_2O_3 \cdot B_2O_3 \cdot 6SiO_2 \cdot H_2O$, containing 5.5 percent B_2O_3; tourmaline, $H_9Al_3(B,OH)_2Si_4O_{19}$, about 6.6 percent B_2O_3; axinite, $HCa_3(Mn,Fe)BAl_2Si_4O_{16}$, about 6.2 percent B_2O_3; and ludwigite, $(Mg,Fe)_2O_2FeBO_3$, about 7.7 percent B_2O_3.

Geology—The commercial borates occur in solution and in saline crusts around and in the muds of playa lakes and in older sedimentary rocks which represent ancient playa lake deposits. The borosilicate minerals are widely distributed in igneous rocks, particularly the granitic rocks.

Occurrences

The Washington occurrences of borates, tourmaline, and dumortierite are discussed under miscellaneous nonmetallic minerals in Part I of this report. Axinite has been found in the Blewett district in Chelan County and near Anacortes in Skagit County. Ludwigite has been reported[2] in considerable quantity at the Read iron deposit in Stevens County, described here in Part II on page 204.

[2] Broughton, W. A., Some magnetite deposits of Stevens and Okanogan Counties, Washington: Washington Div. Geol. Rept. Inv. 14, p. 14, 1945.

CADMIUM

Properties—Cadmium is a soft bluish-white malleable and ductile metal. It is similar chemically and in appearance to zinc, with which it is usually found associated, but it is more malleable and ductile than zinc. It is easily fusible, is corrosion-resistant, and capable of taking a high polish. In most of its compounds it is bivalent. Other properties are shown in the table on page 12.

Uses—The largest use is as a protective coating on iron and steel, and in most respects it is better for this purpose than is zinc. In alloys with nickel, copper, and silver, cadmium is used in important quantities as bearing metal for heavy-duty applications. The third most important use is in the form of its compounds with sulfur and selenium as pigments in paint, rubber, ceramics, ink, and other products. Some of the cadmium alloys, such as Woods metal (12.5% cadmium), have very low melting points and are used in applications where this property is required, such as for electric fuses and automatic sprinklers. The metal has uses in atomic energy technology, in aluminum solder, and in electrical conductor wires. Small additions of cadmium increase the strength of copper wire without sacrificing conductivity. Cadmium compounds are used as insecticides, in medicine, photography, ceramics, and as phosphors. They also have other minor uses.

Production—All cadmium production is as a byproduct of smelting zinc-bearing ores. In 1950 there were 13 plants producing the metal in the United States. In Washington, cadmium has been found in zinc-lead ores in Pend Oreille, Stevens, and Ferry Counties, and although no records are available it is known that smelter payments have been made, in part, on the basis of the cadmium content of some of these ores which were shipped primarily for their zinc values.

Prices—Cadmium was quoted at $3.20 per pound in Germany in 1875. The price was $1.00 in the United States in 1906, when production first started in this country. The price continued to drop to 52 cents by 1909, then rose to $1.56 in 1916, and dropped to an average of 55 cents for the period 1931 to 1934. It rose to $1.22 in 1937, only to drop back to 59 cents in 1939, and then start a rise to the high of $2.55 in 1950 and 1952. In December 1953 the price was $2.00 per pound, but shortly thereafter it dropped to $1.70, where it remained through June 1955.

Ore minerals—Only the rare sulfide, greenockite, CdS, containing 77.8 percent cadmium; the oxide, cadmium oxide, CdO, containing 87.5 percent cadium; and the carbonate, octavite, contain cadmium as the chief constituents.

Geology—No deposits of cadmium ore are known, but greenockite is fairly commonly associated with sphalerite as a greenish-yellow earthy coating. As such it is a secondary deposit, the cadmium probably being derived from alteration of cadmium-bearing sphalerite. Any ore in which there is sphalerite might also contain cadmium. The zinc concentrates from the Tri-State district average about 0.35 percent cadmium, but western zinc concentrates seldom contain more than 0.2 percent.

Occurrences

The map showing the numbered cadmium occurrences is plate 3, on page 11 in volume 2.

FERRY COUNTY

Laurier
(see Talisman under copper)

Talisman (1)
(see under copper)

PEND OREILLE COUNTY

American Zinc, Lead and Smelting Co.
(see under zinc)

Bella May (new adit) (3)
(see under zinc)

Clark
(see Josephine under zinc)

Grandview mine (2)
(see under zinc)

Josephine (1)
(see under zinc)

Pend Oreille Mines & Metals Co.
(see under zinc)

STEVENS COUNTY

Admiral Consolidated (2)
(see under zinc)

Boundary Silver Lead
(see Lucile under zinc)

Clugston
(see Silver Trail under lead)

Dead Medicine
(see Silver Trail under lead)

Longshot (5)
(see under lead)

Lucile (1)
(see under zinc)

Moonlite
(see Morning under silver)

Morning (4)
(see under silver)

Newland
(see Longshot under lead)

Owen
(see Lucile under zinc)

Pioneer
(see Longshot under lead)

Silver Trail (3)
(see under lead)

CALCIUM

Properties—Calcium is a lustrous silver-white malleable and ductile metal which is nearly as soft as lead. It is light in weight, being only about one and a half times as heavy as water. Calcium is the fifth most abundant element in the earth's crust, comprising 3.6 percent of the outer 10-mile shell. It is one of the alkaline earth elements, chemically similar to strontium and barium. It has a strong affinity for oxygen, tarnishes readily, reacts with water, and burns with a brilliant crimson flame. Other properties are shown in the table on page 12.

Uses—Metallic calcium and calcium-silicon, calcium-manganese, and other alloys are used as deoxidizers and scavengers in steel making. The element has some use as an alloy constituent with ferrous and nonferrous metals. Up to 0.35 percent of calcium is added to magnesium to reduce heat-treating time and improve the surface of castings. In additions of up to 0.5 percent it hardens and strengthens lead, and in this use it is an important substitute for antimony. It also substitutes for tin in some lead alloys. Calcium is used as a "getter" in vacuum tubes, and is used as a reducing agent in processes for the recovery of uranium, titanium, and vanadium from their ores. Calcium minerals and compounds have many important large-scale uses in industry, the building trades, and agriculture, but these uses are all in the classification of industrial, or nonmetallic, minerals.

Production—The first commercial production of metallic calcium in this country was in 1936. In 1950 there were only two producers, one in Michigan and one in Connecticut. Since calcium minerals are extremely abundant and widely distributed throughout the United States, it is obvious that factors other than occurrences of the "ore" control the amount of the metal produced and the location of the producing plants.

Prices—Up to 1918 the price of metallic calcium was at or above $20 per pound, thus restricting the metal to only minor uses. Later the price dropped to $1.50, and in 1938 to 65 cents a pound. In 1941 it was $1.25, in 1944 it rose to $1.85, in 1948 to $1.95, and in 1949 to $2.05, where it remained through June 1955.

Ore minerals—Calcium never occurs free in nature but is combined most commonly as the carbonates, calcite, $CaCO_3$, containing 40.0 percent calcium, and dolomite, $CaMg(CO_3)_2$, containing 21.7 percent calcium; less commonly as the sulfates, gypsum, $CaSO_4 \cdot 2H_2O$, containing 23.2 percent calcium, and anhydrite, $CaSO_4$, containing 29.4 percent calcium; and the fluoride, fluorite, CaF_2, containing 51.1 percent calcium. Calcium is an essential constituent of many abundant rock-forming silicate minerals, especially anorthite and the other plagioclase feldspars, the amphiboles, the pyroxenes, garnet, epidote, and scapolite.

Geology—Calcite and dolomite, which might be considered the principal ores of calcium, are two of the most common of minerals, occurring in all three major rock classes—sedimentary, igneous, and metamorphic. The calcium sulfate minerals likewise are widely distributed, and the silicate minerals containing calcium are extremely common and abundant in almost all rock types.

Occurrences

The occurrences of dolomite, calcium carbonate rocks (under limestone), and gypsum are listed in Part I of this report.

CERIUM

Properties—Cerium is the commonest of the group of 15 rare-earth elements. Pure cerium is seldom produced, except experimentally, as the properties of the rare earths are so similar, and they can be separated only with difficulty. Commercial cerium usually includes five rare-earth elements, in the following approximate percentages: cerium, 45; lanthanum, 25; neodymium and praseodymium, 15; and samarium, 10. Cerium is a lustrous iron-gray malleable and very ductile metal which is about as soft as lead. Of all the metals it has the greatest coefficient of expansion. It conducts electricity poorly and heat fairly well. It is a powerful reducing agent, and is attacked slowly by cold water and more rapidly by hot water. Other properties are shown in the table on page 12.

Uses—The best known use of cerium is as misch metal, alloyed with iron to give a brittle product which emits copious sparks when abraded and which is used for lighter flints. Another well-known, but declining use is as a minor constituent with thorium in treating gas mantles. Cerium is used in the cores of carbon electrodes for arc lights, and its compounds are used in optical glass, in the ceramic and textile industries, and in medicine. Cerium is alloyed with aluminum and magnesium for strength and hardness, it is added to special kinds of nodular cast iron, and in steel it confers hot workability and strength. In the past, only a few hundred pounds per year of cerium metal were consumed in this country, but the discovery in 1949 of very large reserves (one estimate gives 3 billion pounds) of high-grade rare-earth ores in California has opened up the possibility for development of entirely new large-scale uses. Large expansion of production should bring the price down, and lower prices for the metal may be expected to result in a large increase in its use in steel manufacture.

Production—In 1950 there were only three important producers of cerium or misch metal in this country, and these were all located in New York or New Jersey. The domestic ore is largely monazite from placers in Idaho and Florida, but the California bastnaesite ores may be in production in the near future. Although monazite is known to occur in placer sands in Washington, and as a minor constituent of pegmatitic phases of granite in the Sherman Pass region of Ferry County, none has yet been produced.

Prices—The prices of cerium metal, misch metal, and cerium alloys have not changed greatly in recent years. In 1928 ferrocerium sold at from $5.75 to $8.00 per pound, and in 1950 the price was $8.00. In 1935 ferrocerium and misch metal sold at $6.00 to $10.00, and in 1950 misch metal was $4.50 per pound. Cerium metal was quoted at $25.00 per pound both in 1935 and 1950.

Ore minerals—The principal ore of cerium has been monazite, a phosphate, (Ce,La,Di)PO_4, containing about 32 percent Ce_2O_3 and about 65 percent rare earths; but large deposits in California of bastnaesite, a fluorcarbonate of cerium and other rare earths, (Ce,F)CO_3, containing up to 40 percent rare-earth oxides, probably will be an important source of ore in the future. Allanite (orthite), a complex silicate of thorium, cerium and other rare earths, aluminum, iron, and calcium has been reported in Washington. There are several dozen rare-earth fluorides, carbonates, silicates, fluosilicates, phosphates, titanates, tantalates, and columbates.

Geology—The rare earths are not really as rare as they seem. In reality they are more abundant than zinc, lead, or arsenic, but they are widely and sparsely disseminated, mostly as monazite, in igneous rocks, especially granites, gneisses, and pegmatites. They rarely make up more than a very small fraction of 1 percent of the containing rock. The only common type of concentration is in placer stream gravels and beach sands. Bastnaesite associated with barite and fluorite has been found in commercial-grade concentrations in lode deposits.

OCCURRENCES

The map showing the numbered cerium occurrences is plate 3, on page 11 in volume 2.

DOUGLAS COUNTY

Columbia River Placer
(see under gold, placer)

FERRY COUNTY

Sherman Creek Pass (2)
(see under uranium)

Wilmont Bar Placer (1)
(see under gold, placer)

GRAYS HARBOR COUNTY

Moclips Placer (1)

Loc: Beach at Moclips. **Ore:** Cerium, thorium. **Ore min:** Monazite, chromite, zircon. **Gangue:** Olivine, quartz. **Deposit:** Ocean beach sand. **Assays:** Sample of natural beach sand showed 71 5 lb. monazite, 24 lb. chromite, 82 lb. ilmenite, and 17¢ gold and platinum per ton. **Ref: 38,** p. 160. **38-A,** pp. 1218-1219. **126,** p. 14.

KING COUNTY

Seattle Placer
(see under gold, placer)

Snoqualmie
(see under thorium)

OKANOGAN COUNTY

Happy Hill (1)
(see under uranium)

PEND OREILLE COUNTY

Dry Canyon (1)
(see under thorium)

CHROMIUM

Properties—Chromium is a bluish-white metal which has a high luster and is capable of taking a brilliant polish. It is tough, resistant to corrosion, and fairly ductile. At temperatures up to 300° C. chromium is not oxidized or corroded by air, oxygen, or chlorine. Electrolytic chromium is malleable, but metal produced by chemical reduction is brittle. Likewise, cast chromium has a hardness of 4 to 5, but chromium plating (electrolytic) has a hardness of 9, which is harder than case-hardened steel. The soluble compounds are very poisonous. Other properties are given in the table on page 12.

Uses—The uses of chromium may be listed under three categories—metallurgical, refractory, and chemical—which normally account for about 47, 37, and 16 percent respectively of the total. Perhaps the best known application, chrome plating on steel, actually uses only insignificant quantities of the metal. Chromium is the most commonly used of all the alloying elements. Increasing quantities are being used in aluminum and copper alloys, but by far the greater portion of the metallurgical chromium is used in steels. More than 30 kinds of stainless steels, with chromium as the chief alloy element, are currently made in the United States. Other chromium steels are low-alloy steels, high-temperature steels, and high-speed tool steels, in which chromium imparts increased hardness, tensile strength, and ductility. Chromium is used in refractories not as a metal but as the mineral chromite, which is used as bricks and cement for metallurgical furnace linings, particularly steel furnaces. Chemical compounds of chromium are used in pigments, tanning, dyes, textiles, and electroplating.

Production—Most of the chromite consumed in this country normally is imported, but during World Wars I and II domestic production increased greatly, only to drop back to negligible amounts after the wars. Very small shipments have been made from deposits in Washington (200 tons prior to 1932), but most of the domestic production comes from southern Oregon and northern California.

Prices—Chromium metal in 1946 was quoted at 89 cents per pound, in 1948 at 93 cents to $1.03 per pound, and in 1951 at an average of $1.07 per pound. In March 1953 chromium metal, 97-percent pure, sold at $1.25 per pound, and 99-percent pure electrolytic metal at from $3.00 to $4.50 per pound. Chromite is sold in three grades. Metallurgical grade should contain a minimum of 48 percent Cr_2O_3, have a chrome-iron ratio of not less than 3 to 1, and have a hard lumpy structure, with pieces ranging from ½ inch to 6 inches in size. Refractory and chemical grades may contain less Cr_2O_3 and have lower chrome-iron ratios. These grades sell for about one-half to two-thirds the price of metallurgical chromite ores. Chromite rose from $11.20 per ton in 1915 to a high of $48.00 in 1918, then dropped back to $10.28 by 1921. From 1922 through 1939 the price remained very close to $20.00. During World War II the price rose to a maximum of $52.80, but by 1948 had dropped to $25.00 to $45.00 per ton, depending upon the grade of the ore. Turkish chromite was quoted in March 1953 at $55.00 per long ton, 48 percent Cr_2O_3, 3 to 1 chrome-iron ratio, but Rhodesian ore of the same grade was quoted at only $44.00 per ton, and Rhodesian chromite containing 48 percent Cr_2O_3 but having 2.8 to 1 ratio sold for $40.00 Domestic chromite delivered to the Grants Pass, Oregon, depot of the General Services Administration was bought by the government in 1953 at $115 per ton for lump ore and $110 for fines and concentrates containing 48 percent Cr_2O_3 and having a chrome-iron ratio of 3 to 1.

Ore minerals—The only commercial source of chromium is chromite, $FeCr_2O_4$. The pure mineral contains 68 percent Cr_2O_3, but it is rarely found in nature. Magnesium and aluminum commonly replace part of the iron and chromium, so that commercial chromite ores seldom contain more than 50 percent Cr_2O_3, and they may contain up to 20 percent each of MgO and Al_2O_3. Chromium-bearing minerals other than chromite which occur in Washington are the green garnet, uvarovite, $3CaO \cdot Cr_2O_3 \cdot 3SiO_2$, containing 30.6 percent Cr_2O_3; the lavender-colored chrome chlorite, kammererite; a chrome-bearing amphibole; and a chrome-bearing clinopyroxene.

Geology—Chromium deposits may be classified as (1) layered, (2) pods, (3) lateritic iron, and (4) placer. The layered deposits are those in which chromite occurs in layers in the lower parts of sheet-like peridotite bodies whose areas commonly are measured in tens of square miles. The chromite layers are from a few inches to several feet thick and from a few hundred feet to several miles long, and they may contain 20 to 22 percent Cr_2O_3, as at Stillwater, Montana, up to 40 to 45 percent, as in the African deposits. The pod deposits are lenticular masses or individual grains of chromite randomly scattered in peridotite or serpentine. The pods may vary from a few pounds to more than a million tons. There are several deposits of this type in Washington, as well as several lateritic iron deposits which contain up to 3 percent Cr_2O_3. The lateritic iron deposits form by tropical weathering of serpentine or peridotite and may cover large areas. Chromite occurs as a constituent of black sands, most commonly in beach placers, but few, if any, such deposits have been of high enough grade to be workable at a profit.

Occurrences

The map showing the numbered chromium occurrences is plate 4, on page 13 in volume 2.

CHELAN COUNTY

Blewett (5)
(see under iron)

Davenport
(see Nigger Creek under iron)

Hardcash (1)
(see under nickel)

Keefer Brothers
(see under molybdenum)

Lucky Queen (4)
(see under gold)

Nigger Creek (2)

Loc: SW¼ sec. 12, (22-16E), just E. of the divide between Nigger and Stafford Creeks. **Elev:** 5,800 ft. **Access:** About 4 mi. of trail from the end of Nigger Cr. road. **Prop:** No claim or lease on the property (1943). **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** No ore has been found in place, but several pieces of nearly pure chromite float weighing about 3 lb. each were found in 1942. **Ref: 67**, p. 15.

Nigger Creek (Davenport) (3)
(see under iron)

Washington Nickel
(see Blewett under iron)

CLALLAM COUNTY

Cedar Creek Placer (1)
(see under gold, placer)

Starbuck Placer
(see Cedar Creek Placer under gold, placer)

DOUGLAS COUNTY

Columbia River Placer
(see under gold, placer)

FERRY COUNTY

Danville (1)

Loc: Near center sec. 16, (40-34E), E. of Kettle River. **Elev:** 2,300 ft. **Access:** 2 mi. by road from railroad at Danville. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Serpentine. **Deposit:** Disseminated fine grains of chromite in a zone 2 ft. wide and exposed for length of 5 ft. in a roadcut. **Assays:** One sample showed 34.2% Cr_2O_3 and had a Cr/Fe ratio of 2.02. **Ref: 158.**

Gemini (2)

Loc: 11.7 mi. NW. of Nespelem, at Cache Cr. summit. **Elev:** 4,000 ft. **Access:** Road. **Owner:** Gemini Mines, Inc., Wenatchee, Wash. (1940). **Ore:** Chromium, beryllium. **Ore min:** Chromite, uvarovite, beryl. **Ref: 58**, p. 23. **158.**

Keller (3)

Loc: Keller dist. **Owner:** M. W. Sumerlin, Keller, Wash. (1953——). **Ore:** Chromium. **Ore min:** Chromite, kammererite. **Ref: 158.**

KING COUNTY

Baring (1)

Loc: N½SE¼ sec. 10, (26-10E), 1¼ mi. S. of Baring. **Owner:** W. R. Anderson (1944). **Ore:** Chromium. **Ref: 158. 165**, sec. II-C, p. 23.

Seattle Placer
(see under gold, placer)

KITTITAS COUNTY

Balfour Guthrie
(see Cle Elum River under iron)

Bean Creek (8)
(see under iron)

Boulder Creek (Burke) (2)

Loc: SE¼NE¼ sec. 35, (23-14E), on W. slope of Mt. Hawkins. **Elev:** 3,500 ft. **Access:** ½ mi. by trail from Cle Elum R. road. **Owner:** Frank Bryant, Cle Elum, Wash., had option to buy from the Northern Pacific Railway Co. (1942). **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Small lens mined out during World War I. A few hundred pounds of ore on the dump. Chromite occurs in serpentinized peridotite. **Dev:** Two short adits, some open cuts. **Assays:** About 50% Cr_2O_3. **Prod:** 1 carload of mixed ore from this and the Crowe property in sec. 33. **Ref: 123**, p. 65. **130**, p. 62. **158.**

Burke
(see Boulder Creek)

Cle Elum River, north deposit (1)
(see under iron)

Cle Elum River, south deposit (4)
(see under iron)

Crowe
(see Mount Hawkins)

Denney (3)

Loc: NE¼ sec. 36, (23-14E), on nose of ridge. **Elev:** 5,200 to 5,500 ft. **Access:** 1 mi. NE. of end of Denney road. 18 mi. by road to railroad at Ronald. **Owner:** Fred Denney, Horton M. Douglas, Chris Ludker, Seattle, Wash. (1942). **Ore:** Chromium, nickel, mercury, gold. **Ore min:** Chromite, reportedly cinnabar. **Gangue:** Peridotite. **Deposit:** Small pods and disseminations of chromite in serpentine. Also on the property is an exposure of "nickel ledge" rock. **Dev:** Open cuts. **Improv:** Cabin (1952). **Ref: 158.**

Devine
(see under iron)

Gallagher Head
(see Mount Hawkins)

Iron Peak (6)
(see under iron)

Kittitas Placer
(see under gold, placer)

Mount Hawkins (Crowe, Gallagher Head, Skipper) (5)

Loc: SW¼NW¼ sec. 33, (23-15E), in Drew Cr. drainage on SE. slope of Mt. Hawkins, near small lake. **Elev:** 6,000 ft. **Access:** 24 mi. by road from railroad at Ronald, 6 mi. of which is steep mountain road. **Prop:** 9 claims: Chrome Compass, Don, Scoup, Last Wagon, Hope, Mary Ann, Homesite, Vision, June. **Owner:** Skipper Chrome Mining Co., Seattle, Wash., leasing from Jack Crowe, Cle Elum, Wash. (1942). Richard Denney

(1920). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Serpentine. **Deposit:** Lenses and lumps of chromite, containing 10% to 20% gangue, strung out in a band of shearing in serpentinized peridotite. Largest lens was 6 ft. wide. One lens was 2 ft. wide, 25 ft. long, 7 ft. deep. Ore largely mined out (1943). **Dev:** 100-ft. trench. **Assays:** 15 tons av. 50% Cr_2O_3. **Prod:** 15 tons of ore during World War I. A carload of ore in 1942. **Ref: 70. 123,** p. 65. **130,** p. 62. **157. 158.**

Red Rock (11)
(see under nickel)

Skipper
(see Mount Hawkins)

Stafford Creek (10)
(see under iron)

Standup Creek (9)
Loc: Sec. 9, (22-16E), on Standup Cr. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** "Nickel ledge" about 25 ft. wide contains a lens of chromite 4 in. in diameter. **Ref: 158.**

Teanaway (7)
(see under iron)

OKANOGAN COUNTY

Blackbird (5)
Loc: SE¼ sec. 11, (39-25E), Nighthawk dist. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Finely disseminated grains in partially serpentinized dunite. **Ref: 158.**

Brown Lake (7)
Loc: Near W. ¼ cor. sec. 6, (34-26E). **Access:** Road. **Prop:** Deeded land. **Owner:** Lloyd Austin, Omak, Wash. (1943). **Ore:** Chromium. **Ore min:** Mariposite (?), chrome chlorite (?), chromite, pyrrhotite. **Gangue:** Quartzite, serpentine. **Deposit:** Chromiferous green quartzite several acres in extent is underlain by peridotite. Also a small lens of chromite about 1½ ft. long in the serpentine. **Dev:** Open pits. **Assays:** Spectrograph shows 0.6% chromium in the quartzite. **Ref: 158.**

Cabin
(see Stepstone under nickel)

Chopaka (1)
Loc: Near W. ¼ cor. sec. 13, (40-24E), near top of Mt. Chopaka. **Elev:** 7,500 ft. **Access:** Trail. **Ore:** Chromium. **Ore min:** Chromite, magnetite. **Gangue:** Olivine, serpentine. **Deposit:** Chromite occurs as disseminated grains and as bands 3 or 4 in. wide in dunite. Chromite is also found as ⅛-in. veinlets along a fault in the dunite. Most bands 1½ ft. or less in length. **Dev:** 8-ft. shaft. **Assays:** 5% chromite in restricted areas. **Ref: 70. 141,** p. 59. **158.**

Defense
(see Little Chopaka)

Dorian (6)
Loc: NW¼SE¼ sec. 34, (35-25E). **Elev:** 2,600 ft. **Access:** 5 mi. by road SE. of old town of Ruby. **Ore:** Chromium. **Ore min:** Mariposite, pyrite. **Deposit:** Sericitic quartzite contains small flakes of mariposite along lamination and fracture planes. **Dev:** Open cuts. **Ref: 75,** p. 36.

Double Eagle
(see Dry Bone under lead)

Dry Bone
(see under lead)

Duke of Windsor
(see Dry Bone under lead)

Funkhauser
(see Johnson Creek)

Johnson Creek (Funkhauser, Omak) (8)
Loc: NE¼ sec. 5, (34-26E), near intersection of Riverside cut-off with the Omak-Conconully highway. **Elev:** 1,750 ft. **Access:** 6 mi. from Omak by road. **Owner:** Chrome Cliff Mining Co., Prosser, Wash. (1955——). Frank Funkhauser, Spokane, Wash. (1951——). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Serpentine. **Deposit:** Chromite disseminated sparsely through ultrabasic rock. Near the ultrabasic-dolomite contact is a tabular body of nearly solid chromite 7½ ft. by 6 ft. by 3 ft. A small stringer about 2 in. wide and 18 in. long is about 10 ft. N. of the main pod. **Assays:** Chip sample across 5-ft. face of ore showed 26.88% Cr, 12.03% Fe, which gives a Cr/Fe ratio of 2.23. Another 5-ft. channel sample showed 42.85% Cr_2O_3, 10.65% Fe, which gives a Cr/Fe ratio of 2.75. A 5-ft. channel sample in the serpentine showed 11.35% Cr_2O_3. **Prod:** 5.9 tons assaying 42% Cr_2O_3 and having Cr/Fe ratio of 2.9 (1955). **Ref: 157. 158. 171,** pp. 21, 23, 30.

Jumbo (9)
(see also Stepstone under nickel)
Loc: Near center SW¼ sec. 32, (33-31E), Nespelem dist. **Access:** 2.8 mi. up Stepstone Cr. road from Park City road. **Prop:** 1 claim (Jumbo) of the present Stepstone property. **Owner:** Mrs. Mamie Bowman (1943). Silver Creek M. & M. Co. (1915). **Ore:** Chromium, copper, nickel. **Ore min:** Chromite, chalcopyrite, pyrite, fuchsite, genthite. **Gangue:** Quartz. **Deposit:** Series of limestone, serpentine, and argillite cut in places by quartz veinlets. Veinlets and portions of the wall rocks mineralized. **Dev:** Adit and open pit. **Assays:** One 3-in. band of chromite and a 1-ft. band of sheared quartz containing considerable percentage of chromite. **Ref: 122,** p. 85.

Little Chopaka (Defense) (2)
(see also Peerless under copper)
Loc: SW¼SE¼ sec. 16, (40-25E), on Little Chopaka Mtn., Nighthawk dist. **Prop:** 4 claims. Probably part of the Peerless property. **Owner:** William Bridey and L. H. Everett (1941). **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Small peridotite mass in schist is ⅛ to ¼ mi. wide and ½ mi. long. In the mass are small pods of chromite. **Dev:** Open cut. **Assays:** 27.06% Cr_2O_3. **Ref: 54,** p. 25. **158.**

Mohawk (11)
(see under zinc)

Okanogan
Loc: Near Okanogan. **Ore:** Chromium, platinum. **Ore min:** Chromite, platinum. **Deposit:** Chromite-bearing serpentine dike. **Assays:** ¼ oz. Pt, Os, Ir together per ton reported by C. W. Smith of Oroville. **Ref: 123,** p. 10.

Omak
(see Johnson Creek)

Peerless (3)
(see under copper)

Stepstone (10)
(see under nickel)

Tonasket
Loc: On hill near Tonasket. **Prop:** Partly deeded land and partly open land. **Owner:** Vernon A. Lestrud, Bellingham, Wash. (1944). **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Worthington (4)
(see also Peerless under copper)
Loc: NW¼ sec. 22, (40-25E), on S. slope of Little Chopaka Mtn., Nighthawk dist. **Elev:** 1,250 ft. **Access:** 1 mi. by trail and

3½ mi. by road from railroad at Nighthawk. **Prop:** Probably part of the Peerless property. **Owner:** Roy R. Worthington, Omak, Wash. (1951). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Peridotite. **Deposit:** Lower open cut shows an irregular stringer of chromite 1 in. wide. The peridotite near the cuts contains a few grains of disseminated chromite. **Dev:** 2 open cuts about 100 ft. above the river and about 50 ft. apart. **Ref: 157.**

SKAGIT COUNTY

Anacortes (8)

Loc: Near Anacortes. **Ore:** Chromium, platinum. **Ore min:** Chromite, said to contain platinum. **Ref: 97,** 1905, p. 424. **141,** p. 103.

Anacortes Placer

(see under gold, placer)

Bellingham (11)

Loc: Secs. 5 and 8, (36-7E). **Elev:** 4,000 to 5,000 ft. **Access:** Trail. **Prop:** 32 claims including the Stein. **Owner:** L. H. Coffield et al. (1943). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Ref: 70-A.**

Cultus Mountain (10)

(see under nickel)

Cypress Lake (1)

Loc: SE¼SE¼NW¼ sec. 29, (36-1E), on N. shore of main lake. **Elev:** 1,000 ft. **Access:** Boat from Anacortes and trail from beach. **Owner:** George B. Smith et al. (1918). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Serpentine. **Deposit:** Adit shows only a few disseminated grains of chromite, but an open cut on hill above shows a lens of chromite. **Dev:** 120-ft. caved adit, open cut. **Ref: 123,** p. 64. **130,** p. 61. **141,** pp. 60, 61.

Devils Mountain

(see Mount Vernon under nickel)

Fidalgo Island

Loc: Beaches of Fidalgo Is. **Elev:** Sea level. **Access:** Roads which traverse most of the shoreline of the island. **Ore:** Chromium, gold. **Ore min:** Chromite, gold. **Deposit:** Chromite beach sands. **Assays:** A few specks of Au with considerable chromite sand can be obtained from a pan. **Ref: 126,** p. 10.

Last Chance (2)

Loc: Sec. 29, (36-1E), a short distance S. of a lake on Cypress Is. **Elev:** 1,300 ft. **Access:** Old road from Strawberry Bay. **Prop:** 1 claim. **Owner:** Cypress Chrome Co. (1918). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Serpentine. **Deposit:** Ore bodies made up of chromite grains thickly disseminated in serpentine. **Dev:** 35-ft. adit. **Assays:** About 25% Cr_2O_3. **Prod:** Has produced. **Ref: 70. 92,** p. 175. **123,** p. 64. **141,** p. 61. **171,** pp. 12, 21, 23, 30.

Leader (12)

(see also Three Lakes)

Loc: Secs. 3, 4, (36-7E), near Three Lks. **Access:** 5½ mi. by trail and 20 mi. by road to railroad at Hamilton. **Prop:** 1 claim: Leader. Part of Three Lakes property. **Owner:** Twin Sisters Chrome and Magnesium Corp., Seattle, Wash. (1954——). Alwyn H. Wild had a 15-yr. lease (1940-1955) from Industrial Mining, Inc. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Ore exposed at 3 localities along Three Lakes Cr. Upper deposit is 5½ ft. wide. 30 ft. downstream the zone is 6 ft. wide. 150 ft. farther downstream is the third exposure. Ore is banded and disseminated and is similar to that on the Meadow claim. **Assays:** Appears to be a little higher grade than the ore on the Meadow claim. **Ref: 10,** pp. 23-26. **70-A. 158.**

McMaster (15)

Loc: Near center W½ sec. 10, (36-7E), on Three Lks. Cr. **Access:** Trail. **Prop:** 2 claims: McMaster, Alma. **Owner:** Leased from Industrial Mining, Inc. by Alwyn Wild (1940). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Assays:** Crude ore contains 56.4% Cr_2O_3 and a Cr/Fe ratio of 2.58. **Ref: 70-A.**

Meadow (13)

(see also Three Lakes)

Loc: Secs. 3, 4, (36-7E), near Three Lks. **Access:** 5½ mi. by trail and 20 mi. by road to railroad at Hamilton. **Prop:** 1 claim: Meadow. Part of Three Lakes property. **Owner:** Three Sisters Chrome and Magnesium Corp., Seattle, Wash. (1954——). Alwyn H. Wild had a 15-yr. lease (1940-1955) from Industrial Mining, Inc. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Banded and disseminated ore exposed for 145-ft. width and vertical distance of 50 ft.; and 400 ft. down slope another exposure of disseminated ore is exposed for a distance of 50 ft. and width of 20 to 30 ft. **Assays:** 20 channel samples taken by owner across strike of bands in upper exposure ranged from 4.95% to 25.52% Cr_2O_3. Clean concentrate contains 56.75% Cr_2O_3 and has Cr/Fe ratio of 2.9. An exposed area 170 by 145 ft. av. 9% Cr_2O_3. **Ref: 70-A. 158.**

Mexican Bay

(see Smith)

Mount Vernon (9)

(see under nickel)

Nellie Kelly (3)

Loc: W. of Lk. 1058 on Cypress Is. **Elev:** 1,140 ft. **Access:** 1½ mi. by steep bulldozer road from Strawberry Bay. **Prop:** 1 claim: Nellie Kelly. **Owner:** Ed Kelly and J. M. Wamba. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Knots, stringers, and bunches of chromite in slightly serpentized dunite. **Dev:** Large adit 40 ft. long and 15 ft. wide. **Assays:** Est. av. 10% Cr_2O_3, but the tonnage is very low. **Ref: 158.**

Olivine Hill (7)

Loc: Near SW. cor. SE¼ sec. 4, (35-1E), a short distance W. of triangulation point, on Cypress Is. **Elev:** At tide level. **Access:** Boat from Anacortes. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Sparsely disseminated grains of chromite in fresh unaltered dunite. **Assays:** Ore runs 0.59% chromite. **Ref: 158.**

P & H

(see Three Lakes)

Pacific

(see Mount Vernon under nickel)

Ready Cash (4)

Loc: On steep W. slope of Cypress Is. about ¾ mi. from shore. NE¼NE¼ sec. 30, (36-1E). **Elev:** 1,100 ft. **Access:** Boat from Anacortes. **Prop:** 1 claim: Ready Cash. **Owner:** Cypress Chrome Co. (1918). **Ore:** Chromium. **Ore min:** Chromite, kotschubeite. **Gangue:** Serpentine, hornblende. **Deposit:** Chromite occurs as irregular veinlets an inch or more thick and as bunches or pockets a foot or more in diameter. The surrounding masses of serpentine contain disseminated chromite. **Dev:** Open cut 36 ft. long, 4 to 6 ft. wide and 10 to 12 ft. deep. Also a 10-ft. adit. **Assays:** Ore av. 47.5% Cr_2O_3. Some ore showed 0.006 to 0.245 oz. Pt per ton. **Prod:** 25 tons in 1917, 50 tons in 1918. **Ref: 70. 92,** p. 175. **123,** pp. 63-64. **130,** p. 61. **141,** pp. 60-61. **171,** pp. 12, 17, 21, 23, 30.

Smith (Mexican Bay) (5)

Loc: NE¼SE¼NE¼ sec. 33, (36-1E), on steep hillside just W. of Mexican Bay, Cypress Is. **Elev:** 500 ft. **Access:** Boat from Anacortes. **Prop:** 1 claim. **Owner:** George B. Smith et al. (1918). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Serpentine. **Deposit:** Small bunches and stringers of chromite along a fault zone and in serpentine adjacent to the fault. **Dev:** Short caved drifts, open cut. **Assays:** Ore runs 30% chromite. **Ref: 123,** p. 64. **130,** p. 61. **141,** p. 60.

Smith open cut (6)

Loc: Center SW¼NE¼ sec. 29, (36-1E), N. 4° E. from hill 1262 in sec. 32, E. of main lake, Cypress Is. **Elev:** 1,100 ft. **Access:** Boat from Anacortes. **Owner:** George B. Smith et al. (1918). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Serpentine, olivine. **Deposit:** A 1-ft. band of chromite consisting of several stringers of chromite-rich ore ¼ to ½ in wide. Band exposed for full length of cut. Exposed to height of 6 ft. **Dev:** 30-ft. open cut. **Assays:** Ore runs 30% Cr_2O_3. **Ref: 158.**

Three Lakes (P & H, Wild) (14)
(see also Leader, Meadow)

Loc: Secs. 3 and 4, (36-7E), in area around Three Lks. **Elev:** 2,500 to 4,000 ft. **Access:** 5½ mi. by trail from end of old logging grade. 25 mi. to railroad at Hamilton. **Prop:** 26 claims, including: Shaft, Alamether, Gora, Leader, Meadow, Howard. **Owner:** Twin Sisters Chrome and Magnesium Corp., Seattle, Wash. (1954——). A 15-yr. lease (1940-1955) by Alwyn H. Wild from Industrial Mining, Inc. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** On Leader and Meadow claims is banded and disseminated chromite in a zone up to 145 ft. wide and lenses of pure chromite in dunite. Six chromite lenses from 2 to 8 in. wide occur in a 7½-ft. section of dunite in one place. Other places show lean chromite bands 8 to 16 in. wide. On Alamether claim is a band of disseminated chromite, est. to av. 13% Cr_2O_3, exposed in cliff to width of 80 ft. and height of 100 ft. On Gora claim is a lens, est. to av. 25% Cr_2O_3, from 3 to 30 ft. thick exposed in cliff to height of 300 ft. A band est. to av. 7% Cr_2O_3 is exposed on Shaft claim for less than 20-ft. width and about 300-ft. height. **Dev:** Open cuts, diamond drill holes. **Improv:** Cabin (1951). **Assays:** Crude ore from the Leader had a Cr/Fe ratio of 2.35. Ore from Meadow contained 4.95% to 25.52% Cr_2O_3 and had a Cr/Fe ratio of 2.9. **Ref: 10, pp.** 23-26. **70-A. 157. 158.**

Twin Sisters

Loc: Twin Sisters Mtns. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Olivine. **Deposit:** Chromite occurs as pods, bands, and disseminated grains in dunite. Individual pods are small. **Ref: 130,** pp. 61-62. **140,** p. 59.

Wild
(see Three Lakes)

SNOHOMISH COUNTY

Florence Rae (2)
(see under copper)

Mountain Cedar (1)
(see under copper)

Mystery
(see Mountain Cedar under copper)

Paystreak
(see Mountain Cedar under copper)

STEVENS COUNTY

Mally (1)
(see under iron)

WHATCOM COUNTY

Alaska (31)

Loc: Near center N½ sec. 31, (37-7E), in Twin Sisters Mtns. **Elev:** 5,000 ft. **Access:** Trail. **Prop:** 3 claims. **Owner:** L. H. Coffield et al. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Ref: 158.**

Amos 'n Andy
(see Galbraith)

Anne
(see Robert and Anne)

Bates and Kraemer (28)

Loc: Sec. 25, (37-6E), Twin Sisters area. **Prop:** 2 unpatented claims. **Owner:** James W. Ruel, Lake Charles, La. (1952). **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Boulder Creek (3)

Loc: On Boulder Cr. near Maple Falls. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Chromite float is reported to have been found in Boulder Cr. **Ref: 158.**

Bumper (14)

Loc: Near NE. cor. sec. 13, (37-6E), about 75 ft. S. of Green Cr. and 900 ft. from the foot of the glacier. **Access:** Trail. **Prop:** 1 claim. **Owner:** Mount Baker Chromium Co. (1937). Washington Chrome Co., Seattle, Wash. (1934). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Lens of chromite 35 ft. long and 7 to 15 in. thick at its center. Lens consists of about 50% to 60% chromite. Smaller parallel pods and lenses. **Ref: 158.**

Button

Loc: On the headwaters of S. Fk. Nooksack R., in T. 37 N., R. 7 E., Twin Sisters area. **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Crater
(see Thunder Mountain)

Cultus
(possibly part of Thunder Mountain property)

Loc: Near a branch of Skookum Cr. at NW. end of Twin Sisters Mtns. **Prop:** 1 claim, part of a group of 6 claims. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Outcrop of disseminated ore is 5 ft. wide, 200 ft. long, and shows in bluff to depth of 30 ft. **Assays:** 18.4% Cr_2O_3. Cr/Fe ratio is 2.78. **Ref: 158.**

Danny (21)

Loc: Approx. in N½ sec. 19, (37-7E), near head of S. Fk. Nooksack R., Twin Sisters area, in a cliff about 800 ft. above the valley floor. **Elev:** 4,000 ft. **Access:** Trail. **Prop:** 1 claim. **Owner:** Washington Chrome Co., Seattle, Wash. (1934). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite, chrome, chlorite, chrome hornblende. **Deposit:** Two lenses of nearly solid chromite separated by 6 in. of dunite. Each lens is about 10 ft. wide and exposed for 10 ft. One lens grades into dunite at a depth of 6 ft. **Dev:** Open cut. **Assays:** Crude ore contains 51.7% Cr_2O_3 and has a Cr/Fe ratio of 3.13. **Prod:** 3,000 lb. of ore were sacked and packed to Bellingham in 1934. **Ref: 70. 70-A. 171,** pp. 11-30.

Dare

Loc: E. slope of Twin Sisters Mtns., on headwaters of S. Fk. Nooksack R., in T. 37 N., R. 6 E. **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Diablo (32)

Loc: Reported near the head of the Thunder Cr. arm of Diablo Lk. Approx. sec. 23, (37-13E). **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

E. N. H. (24)

Loc: Sec. 33, (37-7E). **Prop:** 3 unpatented claims. **Owner:** H. H. Hinshaw, Mount Vernon, Wash. (1952). **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Eight Hundred Kings (9)

Loc: E. slope of Twin Sisters Mtns., on headwaters of Sister Cr., T. 37 N., R. 6 E. **Owner:** R. McArthur et al. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Ford

Loc: E. slope of Twin Sisters Mtns., on headwaters of S. Fk. Nooksack R., T. 37 N., Rs. 6 and 7 E. **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Galbraith (Amos 'n Andy) (17)

Loc: S½ sec. 8, (37-7E), on knob E. of Hildebrand Lk., Twin Sisters area. **Elev:** 5,000 ft. **Access:** Trail. **Prop:** 4 claims. **Owner:** A. C. Ross et al. (1934). **Ore:** Chromium. **Ore min:** Chromite, chrome chlorite, uvarovite. **Gangue:** Dunite. **Deposit:** Lens of chromite 5 to 6 ft. thick, and 5 to 6 ft. of adjacent country rock containing chromite stringers. Lens is traceable for 6 to 10 ft. **Assays:** Crude ore contains 44.4% Cr_2O_3 and has a Cr/Fe ratio of 2.86. **Ref: 70-A.**

Good Hope (20)

Loc: SW¼ sec. 18, (37-7E), on head of S. Fk. Nooksack R. **Elev:** 3,100 ft. **Access:** Trail. **Prop:** 1 claim. **Owner:** Washington Chrome Co., Seattle, Wash. (1934). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Lens of chromite in dunite. Hurst reports two 12-in. stringers and one 18-in. stringer of chromite. **Assays:** Sample assayed in 1933 showed 44.09% Cr_2O_3, 23.15% FeO, 2.95% MgO, 8.60% SiO_2, 11.10% Al_2O_3, and traces of P and S. **Ref: 70. 70-A. 158. 171,** pp. 11, 23.

Government (27)

Loc: NE¼ sec. 24, (37-6E), Twin Sisters area. **Ore:** Chromium. **Ref: 158.**

Grant

Loc: Headwaters of S. Fk. Nooksack R. **Prop:** 4 unpatented claims (1952). **Owner:** A. Grant Franklin, Mount Vernon, Wash. (1952). **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Hardscrabble

(see Thunder Mountain)

Harrington (10)

Loc: Sec. 34, (38-7E), Twin Sisters area. **Prop:** 4 unpatented claims. **Owner:** Gladys H. Harrington, Yakima, Wash. (1952). **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Hildebrand (18)

Loc: Adjoining N. side of Hildebrand Lk. on crest of ridge between Green Cr. and S. Fk. Nooksack R. **Prop:** 4 claims. **Owner:** A. C. Ross et al. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Hornet (25)

Loc: Sec. 34, (37-7E), on Granite Cr. **Prop:** 1 unpatented claim. **Owner:** Albert Nielson, Sacramento, Calif. (1952). **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Joan

Loc: Twin Sisters area. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Jordan

Loc: E. slope of Twin Sisters Mtns, on headwaters of S. Fk. Nooksack R., T. 37 N., R. 6 E. **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

King (11)

Loc: Sec. 35, (38-7E), on Middle Fk. Nooksack R. **Prop:** 14 unpatented claims. **Owner:** J. H. King, Seattle Wash. (1952). **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Kraemer

(see Bates and Kraemer)

Lambert (26)

Loc: Near E. line SE¼ sec. 23, (37-6E), on headwaters of N. Fk. of Hayden Cr. **Elev:** 4,000 ft. **Access:** Trail. 15 mi. from railroad at Saxon. **Prop:** 1 claim: Lambert. **Owner:** Yamate Trading Co., Ltd., San Francisco, Calif. (1952). S. S. Lambert, Sumas, Wash. (1942). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** 2 deposits about 800 ft. apart on opposite sides of the creek. N. deposit has several thousand tons of 50% chromite in banded and disseminated ore zone 240 ft. long, up to 50 ft. wide, and having exposed depth of 50 ft. The S. deposit is similar but smaller and lower grade. **Assays:** One sample of crude ore showed 36.92% Cr_2O_3 and a Cr/Fe ratio of 2.65. Another sample, 16.49% Cr_2O_3 and Cr/Fe ratio of 2.65. **Ref: 70-A. 158.**

Last Notch (22)

Loc: Adjoins the Danny on the E. Approx. in N½ sec. 19, (37-7E). **Elev:** 4,000 ft. **Access:** Trail. **Prop:** 1 claim. **Owner:** Washington Chrome Co., Seattle, Wash. (1934). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Ref: 70-A. 158.**

Lone Pine (8)

Loc: On headwaters of Sister Cr., T. 37 N., R. 6 E. **Owner:** Robert McArthur et al. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

M & M (Sister Creek, McArthur) (6)

Loc: W½ sec. 1, (37-6E), on headwaters of Sister Cr. **Access:** Trail. **Prop:** 4 claims. **Owner:** Robert McArthur et al. (1934). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Lens of chromite several feet long and about 1 ft. wide. Float indicates another body or lens above this lens. **Dev:** Open cut. **Assays:** Two samples from this area assayed 37.4% and 41.1% Cr_2O_3. **Ref: 70-A. 158.**

McArthur

(see M & M)

Nooksack (1)

Loc: W. side of Sumas Mtn., S. of an old iron mine in sec. 35, (40-4E). **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** 2 small chromite stringers. Other outcrops reported in this area are covered by slides. **Dev:** Adit. **Ref: 171.**

Odmark

(see Thunder Mountain)

One Thousand Aces (7)

Loc: On headwaters of Sister Cr., T. 37 N., R. 6 E. **Owner:** Robert McArthur et al. **Ore:** Chromium. **Ore min:** Chromite. **Ref. 158.**

Opportunity (19)

Loc: SW¼ sec. 18, (37-7E), in basin at head of S. Fk. Nooksack R. **Elev:** 4,000 ft. **Access:** Trail. **Prop:** 1 claim. **Owner:** Washington Chrome Co., Seattle, Wash. (1937). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Zone in dunite 6 ft. wide and 40 to 50 ft. long contains 10 or 12 discontinuous chromite schlieren, which are composed of 60% chromite and 40% dunite. **Ref: 158.**

Partner

Loc: Headwaters of S. Fk. Nooksack R., T. 37 N., R. 6 E. **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Pat

Loc: E. slope of Twin Sisters Mtns., on headwaters of S. Fk. Nooksack R. **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Pinochle (5)

Loc: On headwaters of Sister Cr., T. 37 N., R. 6 E. **Owner:** Robert McArthur et al. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Rainbow

Loc: 9 mi. N. of Hamilton, in Twin Sisters Mtns. **Owner:** Earl and Howard Scott, Sedro Woolley, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Ranger (15)

Loc: Near S. Fk. Nooksock R., sec. 13, (37-6E). **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Ribbon (16)

Loc: N½ sec. 7, (37-7E), on NW. valley wall of Green Cr. **Elev:** 3,875 ft. **Access:** Trail. **Prop:** 2 claims: Ribbon, Button. **Owner:** Washington Chrome Co., Seattle, Wash. (1934). **Ore:** Chromium. **Ore min:** Chromite, kammererite. **Gangue:** Dunite. **Deposit:** Lenses of chromite in dunite. One lens on Ribbon claim was 20 ft. long and had a max. width of 3 ft. It was mined to a depth of 15 ft. **Dev:** Open cut. **Assays:** Crude ore assayed 51.2% Cr_2O_3 with a Cr/Fe ratio of 3.06. **Prod:** 20 tons of ore from Ribbon claim were sacked and shipped to Bellingham. **Ref: 70-A. 104,** 5/30/33, p. 18; 2/28/37, p. 28. **158. 171,** pp. 11-30.

Robert and Anne

(possibly part of Thunder Mountain property)

Loc: Near a branch of Skookum Cr., at NW. end of Twin Sisters Mtns. **Prop:** 2 claims, part of a group of 6 claims. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Chromite stringers 1 to 6 in. wide and 5 to 20 ft. long. **Ref: 158.**

Second Basin (30)

Loc: W½ sec. 29 and E½ sec. 30, (37-7E), near divide between Second Basin and Third Basin, Twin Sisters area. **Elev:** 4,300 to 4,500 ft. **Access:** Trail. **Prop:** Group of claims. **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** 3 exposed chromite lodes. **Ref: 70-A.**

Seymour Creek

(see Trappers Pride)

Sister Creek

(see M & M)

Sisters

(possibly part of Thunder Mountain property)

Loc: Near a branch of Skookum Cr., at NW. end of Twin Sisters Mtns. **Prop:** 1 claim, part of a group of 6 claims. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Largest band of solid chromite is 1 to 2 ft. wide and 20 ft. long. Other smaller showings. **Assays:** 44.6% Cr_2O_3. **Ref: 158.**

Skookum

(possibly part of Thunder Mountain property)

Loc: Near a branch of Skookum Cr., at NW. end of Twin Sisters Mtns. **Prop:** 1 claim, part of a group of 6 claims. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Outcrop 80 ft. long is 30 ft. wide at S. end and 10 ft. wide at N end. **Assays:** 25.5% Cr_2O_3. **Ref: 158.**

Stein

(see Sumas Mountain)

Sumas Mountain (Stein) (2)

Loc: Sec. 30, (40-5E), on N. end of Sumas Mtn. One occurrence in center, another said to be in NE¼ of the section. **Elev:** 2,500 ft. **Access:** Trail. **Owner:** Leased for 20 yr. in 1952 to Yamate Trading Co., Ltd., San Francisco, Calif. Nooksack Mining Co. (1949). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Serpentine. **Deposit:** A small stringer of chromite in serpentine exposed in center of the section. Said to be a larger body in the NE¼ of the section. **Dev:** An adit at 2,500 ft. altitude near center SE¼NW¼ sec. 30. **Assays:** 38.8% Cr_2O_3 in the ore. Cr/Fe ratio is 2.11. **Ref: 70. 158. 171,** pp. 13-30.

Sumner (29)

Loc: NW¼ sec. 31 and S½SW¼ sec. 30, (37-7E), Twin Sisters area. **Access:** Trail. **Prop:** 19 claims. **Owner:** John W. Brisky, Mount Vernon, Wash. (1943). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Ref: 158.**

Thunder Mountain (Odmark) (12)

Loc: Near W. ¼ cor. sec. 11, (37-6E), on headwaters of Orosino Cr. **Elev:** 5,000 ft. **Access:** Trail. **Prop:** 10 claims including the Hardscrabble and Crater. **Owner:** Albert Odmark (1934). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** Small stringers and streaks of chromite in dunite over an area 50 by 60 ft. in extent. **Assays:** 7 samples of crude ore taken from different places av. 18.2% Cr. **Ref: 70-A. 158.**

Trappers Pride (Seymour Creek) (13)

Loc: SW¼ sec. 2, (37-6E), at head of Seymour Cr., Twin Sisters area. **Elev:** 5,100 ft. **Access:** Trail. **Prop:** 1 claim. **Owner:** L. E. Bradley (1937). **Ore:** Chromium. **Ore min:** Chromite. **Gangue:** Dunite. **Deposit:** 2 parallel stringers of chromite 48 ft. long. Stringers are 1½ to 2 in. wide and separated by 4 to 5 in. of dunite. **Ref: 158.**

Warren

(possibly part of Thunder Mountain property)

Loc: Near a branch of Skookum Cr., at NW. end of Twin Sisters Mtns. **Prop:** 1 claim, part of a group of 6 claims. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Several irregular showings of low-grade ore 5 to 10 ft. wide. **Ref: 158.**

Wells Creek (4)

Loc: On Wells Cr. about 8 mi. E. of Glacier. **Access:** Said to be very inaccessible. **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Chromite is reported to have been found on Wells Cr. **Ref: 158.**

Whistler (23)

Loc: Near center sec. 17, (37-7E), on N. side of S. Fk. Nooksack R. **Elev:** 3,200 ft. **Access:** Trail. **Prop:** 1 claim: Whistler. **Owner:** Washington Chrome Co., Seattle, Wash. (1934). **Ore:** Chromium. **Ore min:** Chromite. **Deposit:** Chromite is banded and disseminated in saxonite. **Assays:** Most of the ore is low grade, but one sample of ore showed 52.8% Cr_2O_3 and had a Cr/Fe ratio of 3.06. **Ref: 70-A. 158.**

Willie

Loc: E. slope of Twin Sisters Mtns., T. 37 N., Rs. 6 and 7 E. **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

Zoanne

Loc: E. slope Twin Sisters Mtns., T. 37 N., Rs. 6 and 7 E. **Owner:** Washington Chrome Co., Seattle, Wash. **Ore:** Chromium. **Ore min:** Chromite. **Ref: 158.**

COBALT

Properties—Cobalt is a silver-white metal which has a pinkish tinge. It is tough and has a hardness of 5.5, slightly harder than iron or nickel. It strongly resembles nickel in appearance and properties, especially in its resistance to corrosion. Cobalt is strongly magnetic, being exceeded in this property only by iron, and it retains its magnetism up to 1150° C. Other properties are shown in the table on page 12.

Uses—The most important use (35 percent in 1950) is as alloys with iron for permanent magnets. The second most important use (27 percent in 1950), and formerly the chief use, is as stellite-type alloys containing 45 to 55 percent cobalt, with chromium, molybdenum, tungsten, and iron. These alloys are hard and strong at high temperatures, even at red heat. They are used for facing machine parts subject to high abrasion and for high-speed tools, surgical instruments, jet-engine parts, and other high-heat uses. Cobalt oxide is a necessary ingredient in nearly all porcelain enamel ground coats, although this use formerly accounted for a larger percentage of consumption than now. Cobalt compounds are used in blue pigments, as driers in paints, and as catalysts in the chemical industries. Small amounts of cobalt are used for plating other metals, and an increasing amount is used as a binder in cemented carbides. A new and increasing use for cobalt is in making the radioactive isotope, cobalt 60, a potent radiotherapeutic agent.

Production—Although the United States is the largest consumer of cobalt, domestic production has remained small and sporadic, but planned production from the Blackbird area in Idaho would supply a sizable portion of the current demand in this country. Most of the imported cobalt now comes from the Belgian Congo, where it is recovered as a byproduct from copper ores. All foreseeable needs for cobalt can be supplied for many years by known reserves in the principal deposits, and few small producers can hope to compete. No cobalt ore has been produced in Washington.

Prices—Cobalt compounds were very rare and expensive until the New Caledonian ores came on the market. The price for cobalt oxide remained between $1.60 and $2.00 per pound for many years between the 1880's and 1909, when the price jumped to $2.50, only to drop to $1.40 in the same year and to continue the decline to as low as 50 cents in 1912. Cobalt and its compounds remained a drug on the market until after 1915, when increased demand brought a strengthening of the market. Cobalt metal sold for as little as $1.00 per pound when the Canadian metal came on the market about 1909. By 1915 the metal price was $1.60. It rose from $1.25 to $2.25 in 1917, and from $2.50 to $6.00, an all-time high, in 1920. After dropping to about $3.00 a pound and remaining there from 1921 to 1923, the price declined to $2.50 and remained near that level through the early 1930's. In 1940 the price for the metal, 97- to 99-percent purity, in kegs of 550 pounds, was $1.50 per pound, and it remained at that price through 1946, but rose to $1.65 in 1948, and was $1.80 in 1949 and 1950. In 1951 the price rose again to $2.40 per pound and remained there through the early part of 1953. By June 1955 the price was $2.60 per pound.

Ore minerals—The principal ore minerals of cobalt are the sulfarsenide, cobaltite, CoAsS, containing 35.5 percent cobalt; the arsenide, smaltite, $CoAs_2$, containing 28.1 percent cobalt; and the sulfide, linnaeite, Co_3S_4, containing 55.8 percent cobalt. Smaltite and linnaeite have been found in Washington, as has also the less common sulfarsenide of cobalt and iron, glaucodot, (Co,Fe)AsS. Near Silverton in Snohomish County is an occurrence of the distinctive pink-colored earthy secondary mineral, erythrite (cobalt bloom), $Co_3As_2O_8 \cdot 8H_2O$. This hydrous cobalt arsenate is seldom abundant enough to make ore, but it frequently serves to call attention to other less easily recognized cobalt ore minerals.

Geology—Cobalt never occurs native (except in meteorites) and never occurs as the only constituent of an ore. It is very commonly associated with nickel and is found in ores of copper, silver, gold, iron, lead, and zinc. As an arsenide it occurs with nickel in ores that in many places carry high values in silver and gold. As a sulfide cobalt occurs with copper and iron minerals. This type of occurrence is exemplified by the deposits in the Blackbird district in Idaho, which contain 0.4 to 1.0 percent cobalt along with 1 to 2 percent copper, 10 to 15 percent iron, 0.5 to 1.5 percent arsenic, and 3 to 13 percent sulfur. Cobalt ores are found as veins in and near igneous rocks and in residual rocks formed by weathering of basic igneous rocks.

OCCURRENCES

The map showing the numbered cobalt occurrences is plate 5, on page 15 in volume 2.

CHELAN COUNTY

Black Republican
(see under copper)

Blue Jay (2)
(see under copper)

Chelan
(see Dick under nickel)

Dick (6)
(see under nickel)

Keefer Brothers (4)
(see under molybdenum)

King Solomon (1)
(see under copper)

Monarch (18)
(see under gold)

Ontario (16)
(see under gold)

Red Butte (19)
(see under gold)

Red Cloud and Tralee
(see under copper)

Tralee
(see Red Cloud and Tralee under copper)

Winesap
(see Dick under nickel)

FERRY COUNTY

Congress (4)
(see under nickel)

Pin Money (1)
(see under gold)

KITTITAS COUNTY

Bonanza
(see Dolphin under copper)

Dolphin (7)
(see under copper)

LEWIS COUNTY

Eagle Peak (1)
(see under copper)

MASON COUNTY

Black and White (1)
(see under copper)

OKANOGAN COUNTY

Pthomigan (1)

Loc: In T. 38 N., R. 17 E., 1½ mi. from Windy Pass. near W. Fk. Pasayten R. **Owner:** Mrs. L. A. Gourlie, Winthrop Wash. (1951——). **Ore:** Cobalt, copper, gold, silver. **Ore min:** Glaucodot, chalcopyrite, pyrite, **Ref: 158.**

PEND OREILLE COUNTY

Bromide
(see La Sota under silver)

Fissure
(see under silver)

La Sota (3)
(see under silver)

Silver Crest
(see La Sota under silver)

Sterling (2)
(see under zinc)

SNOHOMISH COUNTY

Asbestos (3)
(see under nickel)

Big Copper (7)
(see under copper)

Feldt (2)
(see under silver)

Hancock (11)
(see under copper)

Little Chief (6)
(see under copper)

Mackinaw (8)
(see under copper)

Non Pareil (13)
(see under copper)

Weden Creek
(see Mackinaw under copper)

Wild Rose (12)
(see under copper)

STEVENS COUNTY

Daisy
(see Daisy-Tempest under silver)

Daisy-Tempest (7)
(see under silver)

Maki (3)
(see under lead)

New England (2)
(see under zinc)

Rainbow
(see under silver)

Silver Crest
(see under silver)

Silver Mountain
(see Daisy-Tempest under silver)

Stone
(see New England under zinc)

Tempest
(see Daisy-Tempest under silver)

COLUMBIUM (NIOBIUM) and TANTALUM

Columbium and tantalum are described together because they usually occur associated in the same ore deposits, many of their properties are similar, and some of their uses are the same. Despite the fact that the name columbium, commonly used in the United States, has more than 40 years' priority, the International Union of Chemistry in 1949 recommended that the name niobium, favored in some other countries, be adopted for this rare element. However, the name columbium is so well established it likely will continue in common use at least in this country.

Properties—Both columbium and tantalum when polished look like platinum but when unpolished are darker and bluer. They both are very ductile, malleable, tough, and strong. They may be welded, and both are remarkably resistant to corrosion by acids and other chemicals. They commonly have a valence of 5 in their compounds. Tantalum is about equal to mild steel in tensile strength, elasticity, hardness, and thermal conductivity. It has the highest melting point of the metals other than tungsten, and is about twice as heavy as columbium. Other properties are shown in the table on page 12.

Uses—Columbium and tantalum have their most important uses in special steels. They impart high-temperature strength and creep resistance to the low-iron superduty alloys used for jet-engine parts which are exposed to extreme heat and strain. Both elements are used as additions to ordinary stainless steels to improve ductility and reduce their tendency to air-harden. Added to austenitic stainless steels they inhibit intergranular corrosion at high temperatures, making the steel more weldable, more ductile, and more easily drawn and spun. Both columbium and tantalum are used as "getters" or gas removers in electronic vacuum tubes, and tantalum is used, in addition, for tube electrodes. Prior to 1928 columbium metal was rare and had no industrial uses; and even now, although more than five times as much columbium as tantalum is used in the United States, columbium has few uses as the pure metal. It has been used a little for jewelry and tableware, but the principal uses are in alloy steels. On the other hand, tantalum metal and its compounds have several interesting uses, some of them unique. For example, tantalum is used in surgery as a substitute for bone, because it is inert, and flesh will cling to it as to no other foreign substance. The first important use for tantalum, later replaced by tungsten, was as electric-light filaments. Later it was used in equipment to rectify alternating to direct current, but in this use it has been partially displaced by other substances. Tantalum metal, because of its corrosion resistance, is used to line tanks, pipes, and other equipment in certain chemical industries. It has had minor use in pen points and surgical and dental instruments, and has been used as electrodes in electro-refining certain metals. Tantalum carbide is extremely hard and has been used for dies and cutting tools, and the oxide is used in making special lens glass and as a catalyst in making synthetic rubber.

Production—Very little columbium or tantalum ore is produced in the United States. The peak World War II production in this country was in 1943 and amounted to 5,777 pounds of columbite and 9,411 pounds of tantalite, as compared to imports in that year of 2,383,050 and 643,080 pounds, respectively. Essentially all the columbium and tantalum ores produced in 1950 were used by two companies, one in Chicago and the other at Niagara Falls, New York. No ore has been produced in Washington.

Prices—Columbium metal remained at $560 per kilogram ($250 per pound) for rod and $500 per kilogram ($227 per pound) for sheet from 1940 through 1945, and at $280 per kilogram for rod and $250 for sheet from 1948 through 1950. In 1946 columbite ore having a columbium-tantalum ratio of 10 to 1 or greater was paid for at the rate of 55 cents per pound of contained Cb_2O_5, and in 1955 the government was paying $3.40 per pound of contained Cb_2O_5 plus Ta_2O_5 in ore containing 50 percent or more of the combined oxides. Tantalum metal sold at $160 to $200 per kilogram in 1929, at $91 in 1931, $65 to $73 in 1940, $100 to $500 in 1943, and at $160.60 for rod and $143.00 for sheet from 1948 to 1953.

Ore minerals—The only important ore minerals of columbium and tantalum, and the only ones occurring in Washington, are those of the isomorphous series which has for its end members the iron columbate, columbite, $Fe(CbO_3)_2$, containing 82.7 percent Cb_2O_5, and the iron tantalate, tantalite, $Fe(TaO_3)_2$, containing 86.1 percent Ta_2O_5. There is an almost complete gradation from one end member to the other, and neither is found pure. In some varieties the iron is largely replaced by manganese, and in many varieties part of the iron is replaced by small amounts of titanium, tin, and tungsten. Struverite, a tantalum-iron-bearing variety of the titanium oxide, rutile, has been found in large deposits in Malaya. Other columbium-tantalum minerals are the columbo-tantalates, microlite, samarskite, and fergusonite. Microlite contains also calcium and fluorine, and samarskite contains also iron, calcium, and uranium, as well as cerium and other rare earths. Fergusonite is one of many rare earth columbo-tantalates, none of which is known to occur in minable quantities.

Geology—Columbium and tantalum are widely distributed but occur in few deposits of commercial importance. Deposits from which their ores have been recovered are limited to pegmatities in granites and to placers derived from them. However, columbium occurs in very small amounts (0.00003 to 0.031 percent) in many rock types as a substitute for titanium in the titanium accessory minerals, the highest concentrations being in alkalic rocks such as nepheline syenites. Bauxites derived from such rocks are enriched in columbium, and Arkansas bauxites have been found to average 0.05 percent columbium. Of the many pegmatite dikes in the world only a few contain columbite-tantalite and fewer yet in recoverable amounts. The most favorable pegmatites seem to be those in which the feldspar is albite, and within the pegmatite bodies the most favorable zones seem to be those rich in beryl and spodumene.

Occurrences

The map showing the numbered columbium and tantalum occurrences is plate 3, on page 11 in volume 2.

OKANOGAN COUNTY

Arnold Peak
(see Horseshoe Basin under molybdenum)

Horseshoe Basin (1)
(see under molybdenum)

MacPherson
(see Horseshoe Basin under molybdenum)

STEVENS COUNTY

Calispell Peak
(see Cannon under uranium)

Cannon (1)
(see under uranium)

Railway Dike
(see Cannon under uranium)